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# SCIENCE, TECHNOLOGY AND LATE IMPERIAL HISTORY

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*As illustrated in the work of Elman and his school, the demystification of science has opened new vistas in the history of late imperial China. I argue that the similarly demystified concept of technology, as it has recently been elaborated in technology studies, offers equally exciting new opportunities. They include an enrichment of our understanding of late imperial governance, subjectivities and material culture, and new possibilities for organizing, relating and comparing within the history of China, as well as for cross-cultural comparison. The article proposes three organizing concepts, technological landscape, culture, and era/mode, as tools both for exploring late imperial China and for linking China into comparative or global history.*

**KEYWORDS:** *Technology, history of technology, technological culture, technological landscape, China*

Benjamin Elman's meticulous explorations of scientific cultures have set the tone for a radical reframing of how we study late imperial China. Rather than treating science as a specialised epistemological domain set apart from ordinary lives and logics, Elman and his school propose science as integral to society, probing the nature of knowledge clusters, exploring how such technical fields of expertise as philology and mathematics, medicine and cosmology interwove, and demonstrating how they suffused statecraft, politics and culture.

In redefining the nature and scope of technical knowledge and expert practices, the new historiography of science in China draws inspiration from the broader field of critical science studies that has likewise revolutionised and democratised the history of science in the West, while opening the door to societies previously dismissed as having no real science of their own.

As a result, comparative history of science also gains new possibilities. Instead of propounding Western exceptionalism, the empirical and interpretative foundations are laid for much more interesting and productive exercises. Rather than judging and ranking, symmetrical comparisons can become the goal, adopting an anthropological approach that asks how different societies address common problems such as dealing with uncertainty, constituting a scientific corpus or demonstrating a mathematical proof. Typically, in the process of sustained and non-judgemental comparisons of this kind, assumptions are shaken and paradigms challenged for each and every knowledge culture explicitly or implicitly included in the comparison, including that omni-present referent, the European or Western tradition.<sup>1</sup>

The analysis of encounters, exchanges and impact is similarly reconfigured when science is treated as a universal, embedded human activity. Elman's *On Their Own Terms* is a fine example.<sup>2</sup> The European concept of science and its corresponding

hierarchies and clusters of knowledge were first introduced to Chinese intellectuals by the Jesuits. Noting that right up to the debacle of the Sino-Japanese War the intrinsic superiority of Western knowledge remained open to debate among its Chinese interlocutors, Elman argues persuasively for treating the period from 1550 to 1900 as a continuum marked by sustained creative dialogue between knowledge systems, a period throughout which “science” was at the foreground of intellectual and political concerns in China. In order to understand both the history of those crucial centuries and the significance of science in modern and contemporary China, Elman argues, we need to look closely at how late imperial Chinese thinkers produced their own “science”.

Demystifying science and incorporating science-studies approaches into Chinese history has helped build a flourishing field whose power to illuminate the workings of imperial society at all levels is vividly illustrated in the five case-studies presented here by Elman’s former students. Yet despite equally exciting and transformative new directions in the broader fields of technology studies and history of technology, historians of pre-industrial China have so far shown little enthusiasm for mobilising technology as a heuristic.<sup>3</sup> In what follows I first ask why this might be, then propose the case for demystifying technology and integrating it into China’s social, cultural and political history. I suggest that three concepts recently elaborated in technology studies – technological landscapes, technological cultures and technological eras – could usefully serve both for internal and comparative / global.

### **The problem concerning technology**

As Nathan Sivin tartly noted some time ago, asking why something didn’t happen is far less likely to produce interesting history than asking what did —the principle on which most historians of China sensibly enough work.<sup>4</sup> Given how technology has been used and abused in constructing grand narratives for China’s past, it is not surprising that most of them regard the term with misgiving, or dismiss it as the necessary yet culturally uninteresting nuts and bolts that hold a material culture or socio-economic system in place. Although they readily engage with other equally anachronistic concepts and categories like science, gender, religion, art, philosophy, law, property, society or the state, many of which have also been mobilized in the past to bolster evolutionary arguments about Western superiority, today none of these terms seems quite so distorting of Chinese realities, so tainted with positivist agendas and freighted with negative baggage, as technology. In consequence very few historians of China have so far engaged with innovative or critical approaches within the history and sociology of technology.<sup>5</sup>

In part this is an internalist, sinological issue: we are tired of parrying the “Needham Question”, wearied by the apparently unquenchable stream of media claims that the Chinese invented everything from the compass to the flush toilet; most of us are happy to leave “great divergence” debates to the economic or world historians. We find other angles on what made imperial China tick more exciting, and more fruitful. But equally important is the very narrow view of what technology is and means, and how to identify and study it, that still prevails, limiting our imagination of what history of technology could bring to the study of late imperial China.

We live in a world where most people, from technocrats to schoolchildren to academics, believe that technology means iPhones and biotech but not refrigerators, string or latrines; that technology is culture-free and politics-free; that it is a force irresistibly propelling us into the future; and that its history confirms that West is Best (while nervously recognizing that the East is Catching Up Fast). The most popular and influential works in history of technology offer a cornucopia of heroic stories and cultural explanations to confirm this view.<sup>6</sup> As a discipline, the history of technology emerged as an enterprise charting the roots and the rise of the modern West and its path to world supremacy.<sup>7</sup> Even today, the bulk of its scholarship still focuses on modern industrial societies, on trains, planes and automobiles, electrification and nuclear plants, asbestos and rare earths, the training of engineers and the advances of robotics – in other words, on activities and artifacts recognised as key to the shaping of modernity. The field is still marked, moreover, by a strong emphasis on innovation, thus apparently endorsing the popular view that history is structured by a succession of (predominantly Western) inventions catalyzing economic growth, social transformation and societal progress.<sup>8</sup> One can understand why historians of imperial China are seldom tempted to dabble in these waters.

But the caricatural outline I have just presented falls far short of the richness of technology studies today. It has become a highly interdisciplinary and methodologically sophisticated field, drawing on critical theory, cultural studies, feminism, anthropology, literary criticism, aesthetics and environmental history to interface with the more established input from engineering, sociology, business history, urban studies or material science. As in history and social science more generally, technology studies has embraced the turn from production to consumption as constitutive moment, and has become deeply concerned with meanings and subjectivities.

Inventors have not disappeared from our research, but must jostle for attention with users or refusers. An engineer's blue-print is read not just for its technical content but simultaneously for its aesthetic or its politics. "Efficiency" is deconstructed and contextualized. Humble "everyday technologies" like bicycles or corrugated iron are given star roles. We ask how women, children and non-whites became excluded from the circle of recognized technical experts.<sup>9</sup> Histories of gas and electricity compare the sensibilities and subjectivities expressed in lighting choices for domestic, public or official settings in London, St Petersburg or Istanbul.<sup>10</sup> Different phases of statism in France are examined through grand projects: the building of the Canal du Midi under Louis XIV; changes in gun manufacture through the 1789 Revolution and into the Empire; nuclear power in the reconstitution of the French nation post-WWII.<sup>11</sup> In a tantalizing echo of recent investigations of the bound foot, one recent study analyzes the pointe ballet shoes used by Balanchine's New York City Ballet as 'a technology of artistic production and bodily discipline', supporting a dancing style that 'emerged from uniquely twentieth-century systems of labor and production'.<sup>12</sup>

In addition, historians of technology are now becoming interested in what we might call *après*-innovation, in the immense efforts and resources necessary to keep things working. Continuity, from this perspective, is not the natural order of things; *maintenance* is the essential analytical counterpart of innovation and construction.<sup>13</sup> I would take this insight still further. Whether in the historical past or in today's society, one important function of technology is maintaining stability, not simply

material stability (a reliable supply of energy; dykes that resist flood tides; food preservation to smooth over seasonal shortages), but also political, social and cultural stability (weapons to protect borders and keep ruling regimes in power; phones and apps that allow migrant workers to keep in regular touch with their families – or their historical equivalents, including ancestral altars or tombs through which the living communicate with the dead). As material objects and practices that tacitly express shared values and beliefs, technologies can be a powerful force for anchoring institutions, promoting stability through times of upheaval or change. No less energy and creativity go into maintaining continuity, stability and cohesion than into triggering disintegration or revolution, and no less careful explanation is required. This adaptive or conservative potential is an aspect of technology that has been largely ignored, yet it is, to my mind, one of its most interesting features, and offers one promising way to think about technology in late imperial context.<sup>14</sup>

Materialities of governance, material cultures of subjectivity: these are surely themes with inherent appeal for historians of late imperial China. There is no shortage of sources we can profitably explore, or of relevant studies already published, even if few of them as yet are couched in terms of technology. Now let me suggest some strategies for organising these resources and bringing them into conversation.

### **Technological landscapes and cultures**

In its broadest anthropological definition, technology denotes ways of *making* and *doing*. From the anthropological perspective technology is not an automatic force for progress, an attribute of trained specialists or superior civilisations, but a ‘material manifestation of the various ways men and women throughout time have chosen to define and pursue existence’.<sup>15</sup> Thus defined, technology constitutes a robust conceptual tool for rethinking history, encouraging us to explore how societies translated goals, values and regimes of power into material practices and artifacts.

Every society uses tools and technical skills to produce a characteristic life-style, a world that is at once material, social and symbolic. It builds a repertoire of skilled material practices and artifacts to produce food, shelter and clothing; to communicate; to control; to distinguish rank and gender, native and foreign, civilised and uncouth; to worship, to fight or to trade – what we might call its *technological landscape*.<sup>16</sup> It also develops characteristic ideas about the forces mobilised by technological activities of various kinds; about how, whether and to what ends they should or should not be used; the nature of their effects; and their political, moral or metaphysical significance – its *technological culture*.<sup>17</sup> Technological landscape and technological culture are co-constitutive. The technological landscape (resources, materials, skills, artefacts) offers the material and mental *conditions of possibility* for the technological culture; the technological culture (goals, values, ideas about what can be done and how) shapes the *imaginaries* and the *resources* that go into reproducing, modifying and/or developing the technological landscape.

Neither technological landscape nor technological culture will be homogeneous in any society. The technological landscape will include multiple, distinct or overlapping repertoires and assemblages of materials, tools, skills, knowledge and styles. Whether in ancient or modern societies we observe non-synchronicities where old and new, more or less advanced technologies co-exist, serving different

functions, regions or groups – in medieval England, for example, the short-bow and the long-bow, the domestic quern and the manorial mill, or in China today the high-speed train, the bicycle and the wheel-barrow, the microwave and the wok.<sup>18</sup>

Technological cultures vary also, within or between groups or domains of expertise. In today's neoliberal economies, for instance, corporations are likely to argue strongly that innovation should proceed unimpeded as it will ultimately benefit society, while environmentalists press for the precautionary principle to be applied. In sixteenth-century China, in confrontations recalling the differences between modern American and Dutch philosophies of flood-control analyzed by Bijker, imperial officials and hydraulic experts argued over two incompatible models of flood-control policy: either wait till an emergency threatens and then deep-dredge the waterways as rapidly as possible, or allocate regular amounts of money and manpower for routine maintenance and improvement of the channels and dykes.<sup>19</sup>

The concept of *technological landscape* was initially proposed by Svante Lindqvist as a corrective to the presentism of innovation-focused history of technology. Wiebe Bijker offered *technological culture* as a way to analyze and contrast the value systems, risk perception and power relations embedded in such seemingly similar and neutral products of modern engineering as the dykes of the Netherlands and the levees of New Orleans. Both concepts were initially developed as ripostes to the universalizing, depoliticizing, innovation-obsessed claims of modern technocracy, but their potential for illuminating earlier histories and deeper historical legacies is immediately apparent. Adding my own anthropological twist on what falls within the purview of technological matters, I have found both concepts useful for illuminating aspects of late imperial history, as well as continuities and ruptures between imperial and modern China, and for locating China helpfully in world history.<sup>20</sup>

Lindqvist argues that in the contemporary, industrial world, technological landscapes change much more slowly than we might conclude from a narrow focus on innovations. Historians of technology often single out one technology or a closely-knit cluster of technical activities for study. But a fuller *tour d'horizon* is called for, a more detailed mapping of the contours and defining features of the broad technological landscape, its diversity of technologies and technical resources, its superimposed or interdigitated layers of old technologies and new (what philosophers of technology call non-synchronicities<sup>21</sup>), its centres, hinterlands and peripheries, its knowledge clusters and the linkages between different technologies, if we wish to understand the role and significance attributed to our chosen technology within its social context, its patterns of change, and its systemic impact.

As an example, Christian Daniels has drawn attention to the cheap, simple and flexible “technological kit” characteristic of the imperial countryside.<sup>22</sup> The kit included farming tools, notably iron hoes or mattocks and the iron turnplow. The turnplow was ideally suited to rice-farming; it was also key in much commercial cropping, allowing sugar-farmers for example to pursue an intensive cultivation system based on regular spacing of the canes along ridges separated by drainage furrows - a productive system much admired by Europeans used to broadcast fields; and it was an essential tool; it was used by miners (who were often farmers adding to their income in the off-season) to extract coal or iron-ore lying close to the surface and by the ceramics industry to obtain clay. The corresponding “manufacturing kit”

included the Chinese stove and wok; processes of steaming to extract oil or juice; the use of lime as a reagent; and trip-hammers, edge-runner mills, and eventually the roller-mill (apparently derived from the cotton-gin) to express juice or oil from the raw materials.

The complete “technological kit” suited small-scale production admirably: it was cheap and easy to construct; it could be transported from field to field, between farms and workshops, or from river valleys up onto steep mountain slope; and it did not require any concentration of labor to operate. The characteristics of this technological kit, the ease with which it could penetrate new environments (compared, for example, to the much weightier, more expensive and specialized equipment typical of advanced farming in early modern Europe), or switch between rice, sugar, pepper or clay production, fundamentally shaped the farming and manufacturing landscapes of imperial China and its demographic patterns.

In addition to highlighting unevenness and heterogeneity, the concept of technological landscape also prompts us to think about technology as a force for cohesion, where potentially disruptive transformations in one technical domain are contained through adjustments in others, or channeled through or into existing infrastructures, material or institutional – integrative processes that in modern context can be described as *system-building*.<sup>23</sup>

In pre-industrial societies such equilibration occurred less frequently through deliberate intervention and coordination than through more organic processes of adjustment. These have been a core theme in my own studies of the role of technology in the long-term survival of the Chinese late-imperial order. The gradual diffusion of shared norms for domestic architecture, incorporating ancestral altars and the segregation of the sexes, was neither planned nor enforced but rather a case of what Veblen termed emulation. But technocratic intervention was also a key element. The late imperial technological landscape was elaborate and diverse. It contained sophisticated technologies such as canals, chain suspension bridges, water-mills and irrigation pumps, lofty buildings, productive farming, textiles of every kind, an abundance of fine china-ware and a thriving print industry. But rich and sophisticated regions co-existed with impoverished backwaters. One of the enduring concerns of imperial statecraft was to improve life in poor or vulnerable regions. State officials regularly deployed technology (building flood barriers, setting up sericultural projects or public granaries, disseminating new crop plants, etc) to improve local living conditions. The goal was not simply material: replacing local tillage implements and textile equipment with central Chinese plows and looms was considered an effective way to mold non-Chinese into good Chinese subjects; encouraging peasants to adhere to the canonical divisions of labor and of domestic space tied ignorant rustics into webs of orthodoxy.<sup>24</sup>

This example confirms that to understand the work that technology does in any specific context, we need to ask not only how it performs materially, but also how it contributes to building a political, social and symbolic order. Material production is intimately entangled with meaning and value. This is where the concept of *technological culture* comes into play. We as historians will wish to enquire into our historical actors’ beliefs about which technologies are important and why; about their significance, nature and impact; about the forces they mobilise and the sources of

technical skills. The value attributed to a certain kind of work, or skill, or product, may or may not include an estimation of economic worth or material efficacy, in addition to beliefs about its symbolic, political, social or aesthetic value. The significance, and the value, attributed to a particular technology or technical skill may change radically over time, or when a commodity or a technology moves across borders.

Let me give a couple of examples. When the Spanish conquered the Inka empire they took over the exploitation of its gold and silver mines. Silver and gold played a key role in Inka government, not as inert metals but as living forces creating wealth and strength. The living Inka was carried through the streets on a palanquin that made of silver alloyed with gold, glittering like the sun. Alloys were more highly prized than pure metals, for they symbolised the blending of peoples under Inka rule. The Inka rulers valued the silver from one mine, at Porco, especially highly for its “extremely white” color. The white Porco silver was especially precious to the Inka because its whiteness betokened the lightning, the weapon of the supreme deity who bestowed fertility, wealth and military success. The Spanish also esteemed the Porco silver highly, but not because they attached any religious importance to it. To the Spanish, whiteness signalled high metallic purity and greater monetary worth.

The Spanish metric of metallic purity as value is current. However, modern views are quite at variance with another core value of the technological culture of the Spanish empire. Economic historians observe that the Spanish, unlike the Dutch or the Japanese, did not spend their silver wealth wisely. They did not invest in technical or institutional innovations, they did not finance improvements in agriculture or industry. Instead of using capital to generate wealth by developing the means of production, the Spanish monarchs of the Golden Age fostered what Thomas Misa calls “technologies of the court”,<sup>25</sup> technologies that consumed rather than generating wealth. American silver paid for Spanish palaces, cathedrals and roads, for bureaucratic salaries, patronage of the arts and royal regalia, but above all for soldiers and sailors, ships and guns. The Spanish monarchs thirsted for glory: their mission was to stamp out the Reformation and to rule as the foremost power in Europe. To this end they went deeply into debt for wars that they ultimately lost. By today’s economistic standards, the Spanish simply wasted their silver.

Let me turn to an equally striking rupture in technological culture in China, whereby weaving women were transformed, almost overnight, from virtuous subjects to transgressive citizens.<sup>26</sup> ‘Men plough, women weave’ (*nangeng nüzhì* 男耕女織) was a mantra for state officials and ordinary folk alike in imperial China: men’s work in the fields fed the family and the empire, women’s work at spindle and loom, carried out within the house, clothed them. Weaving skills were a mark of virtuous and productive womanhood in China for at least 2,000 years, and handloom weaving by village women continued to provide a significant portion of China’s textile needs through the Republican era.

All this suddenly changed in the 1950s and 1960s under the revolutionary policies of the People’s Republic of China. Women were to be liberated by integrating them into the public workforce. Textile production was to be industrialized. As cotton cloth was one of the fledgling nation’s few reliable foreign-currency earners, cotton-growers were expected to hand over their whole crop for industrial processing, and



peasant families were only allowed to keep a kilo or two for domestic use. The exigencies of female liberation, industrialization and nation-building led to official condemnation and suppression of homespun production, driving women weavers, so to speak, underground. What used to be socially valued work was now a transgression.

### **Technological eras or modes**

Another fruitful concept that could usefully be adapted in late imperial context is the concept of *eras*, as propounded by Thomas Misa in *Leonardo to the Internet*.<sup>27</sup> Including chapters on ‘Technologies of the Court’ and ‘Techniques of Commerce’ in addition to more familiar tropes of ‘Geographies of Industry’,<sup>28</sup> (with beer and brewing in a starring role), ‘Instruments of Empire’ and ‘Means of Destruction’, Misa’s book is a stimulating example of how taking technological cultures and landscapes seriously breathes new life into old narratives about the rise of the West. It also raises intriguing possibilities for developing local histories of technology, as well as for cross-cultural comparison.

As Eda Kranakis notes in her review of the book, Misa’s approach to eras ‘draws on the tradition of political economy’ yet ‘takes an essential step beyond the myth of economic man’.<sup>29</sup> Misa identifies a sequence of eras whose time-frames do not always coincide with conventional historical divisions. They are characterized by key preoccupations or institutions, and Misa links each to a corresponding repertory of key technologies. Rather than arguing that technological developments drove the evolution of social and political institutions, ‘Misa’s model shows technical eras arising out of – and in relation to – specific political and cultural systems. This difference is fundamental, and Misa’s approach therefore provides new insights about the ways in which societies *choose* and *use* technologies’.<sup>30</sup>

Thus, Misa’s essay on ‘Techniques of commerce’ in Holland in the Golden Age portrays it as thoroughly capitalist but not industrial society: its technical developments are better understood not as steps along a unilinear pan-European progress towards industrial mechanization, but rather as a spectrum of efforts to develop the technologies of commerce, in a network linking ship-building and financial tools with new processes for the refinement of sugar or weaving of cashmere. ‘These technologies not only set the stage for a Dutch commercial hegemony that lasted roughly a century; they also shaped the character of Dutch society and culture at all levels and across the entire country.’<sup>31</sup> To my mind this strongly evokes the impact of Daniels’ “technological kit” on regimes of production and consumption in late imperial China. I would love to see a corresponding study of ‘Techniques of commerce’ for the Ming and Qing.

Misa’s European eras are presented, unsurprisingly, as a chronological sequence and indeed they demonstrate a logic of chronological and technical development, from commercial to industrial capitalism and imperialism. I think it would not be impossible to trace a useful succession of technological eras in Chinese history that could provide illuminating perspectives on society and culture. But Misa’s eras are also modes or styles, often overlapping in a single society. In most countries of *ancien régime* Europe ‘technologies of the court’ overlapped with, competed with, or drove ‘techniques of commerce’. In the case of imperial China, we might investigate

the shifting interplay through the early modern period between ‘technologies of the state’, ‘technologies of the court’ and ‘technologies of commerce/work’.<sup>32</sup> In comparative vein, it would also be interesting to compare technologies of the court in early Ming and early Qing China, or in early Qing China and France at the same period.<sup>33</sup>

## **Concluding remarks**

The demystification of science has opened new vistas in the history of late imperial China. I argue that the similarly demystified concept of technology, as it has recently been elaborated in technology studies, offers equally exciting new opportunities. They include an enrichment of our understanding of late imperial governance, subjectivities and material culture, and new possibilities for organizing, relating and comparing within the history of China, as well as for cross-cultural comparison.

Here I have proposed three concepts, technological landscape, culture, and era/mode, as tools both for exploring China and for linking China into comparative or global history. While never losing sight of the material affordances and restrictions that shape technological action, these anthropological approaches to technology as culture, as an embedded element of all aspects of human life and as a material vector of regimes of power, undermine the previous analytical chasm between pre-modern and industrial societies. They challenge the ‘idea of a great divide between modern and pre-modern knowledge systems’, or of historically significant versus ‘outside of modern’ technologies.<sup>34</sup> Their ontological approach to the work that technologies do in a specific social and material context allows us to bypass the compulsive teleologies of typical global or world history, obsessed as they still are with great divergences and convergences.

The concepts of technological landscape, culture or era/mode do not rule out an interest in innovation, but are equally attentive to the energy, ingenuity and skills that go into maintaining stability, and to the role of technologies, present as well as past, in social and cultural reproduction. In other words, as applied even to modern industrial societies, they call upon us to look at significance, efficacy and meaning differently. If we take this approach seriously, whether we are looking at the late imperial printing industry, at contemporary nuclear engineering or at the life-style of palaeolithic hunter-gatherers, we are prompted to question each from the perspective of the other. Symmetrical historical comparisons of this kind are valuable because they challenge our assumptions both about the past that we study, and about the present in which we live.

## NOTES ON CONTRIBUTOR

Francesca Bray is ....

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- <sup>1</sup> On divination and risk see the work of the Erlangen International Consortium on *Fate, freedom and prognostication: strategies for coping with the future in East Asia and Europe*; <http://www.ikgf.uni-erlangen.de/> accessed 12 February 2017. On building a corpus, see Florence Bretelle-Establet (ed), *Looking at it from Asia: The Processes that Shaped the Sources of History of Science*, Springer, 2010. On mathematical proof see Karine Chemla (ed), *The History of Mathematical Proof in Ancient Traditions*, Cambridge University Press, 2012.
- <sup>2</sup> Benjamin Elman, *On Their Own Terms: Science in China, 1550-1900*, Harvard University Press, 2005.
- <sup>3</sup> Dagmar Schäfer (ed), *Cultures of Knowledge: Technology in Chinese History*, Brill: 2012. At the workshop where these papers were first presented, it proved extremely difficult to convince most of the contributors that they were writing about technology.
- <sup>4</sup> Nathan Sivin, 'Why the Scientific Revolution did not take place in China – or didn't it?' *Chinese Science* 5 (1982): 45-66.
- <sup>5</sup> See Francesca Bray, *Technology, Gender and History in Imperial China: Great Transformations Reconsidered*, Routledge, 2013: 23.
- <sup>6</sup> E.g. David S. Landes, *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present*, Cambridge University Press, 1969; Joel Mokyr, *The Lever of Riches: Creativity and Economic Progress*, Oxford University Press, 1990.
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- <sup>8</sup> David Edgerton, 'From innovation to use: ten eclectic theses on the historiography of technology', *History and Technology*, 16, no. 2 (1999): 111-136.
- <sup>9</sup> Jennifer Karns Alexander, *The mantra of efficiency: From waterwheel to social control*, Johns Hopkins University Press, 2008; David Edgerton, *The Shock of the Old: Technology and global history since 1900*, Profile Books, 2011; David Arnold and Erich DeWald, 'Cycles of empowerment? The bicycle and everyday technology in colonial India and Vietnam', *Comparative Studies in Society and History* 53.04 (2011): 971-996; Nina E. Lerman, "'Preparing for the Duties and Practical Business of Life": Technological Knowledge and Social Structure in Mid-19th-Century Philadelphia', *Technology and Culture* 38.1 (1997): 31-59; Nelly Oudshoorn and Trevor Pinch, *How users matter: the co-construction of users and technology*, MIT Press, 2003.
- <sup>10</sup> Graeme Gooday, *Domesticating Electricity: Technology, Uncertainty and Gender 1880-1914*, Pickering and Chatto, 2008; Nurcin Ileri, *A Nocturnal History of Fin du Siècle Istanbul*, PhD thesis, SUNY Binghamton, 2015; Natalia Nikiforova, 'When the phonograph came to Russia', <https://www.leeds.ac.uk/arts/news/article/2780/when-the-phonograph-came-to-russia> [published 12 January 2016, accessed 10 February 2017].
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- <sup>12</sup> Whitney E. Laemmli, 'A case in point: romance and regimentation at the New York City Ballet', *Technology and Culture* 56, 1: 1-27, p.1. On bound feet as

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<sup>13</sup> Lee Vinsel and Andrew Russell, 'Hail the Maintainers', *Aeon* (online magazine <https://aeon.co/essays/innovation-is-overvalued-maintenance-often-matters-more>) [accessed 10 February 2017].

<sup>14</sup> Francesca Bray, 'Technics and civilization in Late Imperial China: an essay in the cultural history of technology', *Osiris* 13 (1999): 11-33.

<sup>15</sup> George Basalla, *The Evolution of Technology*, Cambridge, 1988: 15.

<sup>16</sup> Svante Lindqvist 'Changes in the technological landscape: the temporal dimension in the growth and decline of large technological systems', in Ore Granstrand (ed), *Economics of Technology*, Amsterdam, 1994: 271-288; Jon Sigurdson, 'A New Technological Landscape in China', *China Perspectives* 42: 37-53.

<sup>17</sup> Wiebe Bijker, 'American and Dutch coastal engineering: differences in risk conception and differences in technological culture', *Social Studies of Science* 37 (2007):143-152; Bray, *Technology, Gender and History*: 5.

<sup>18</sup> M. Flitsch, 'Knowledge, embodiment, skill and risk: anthropological perspectives on women's everyday technologies in rural North China', *East Asian Science, Technology and Society* 2, 2 (2008): 265-288.

<sup>19</sup> Cho-ying Li, 'Contending strategies, collaboration among local specialists and officials, and hydrological reform in the late fifteenth-century Lower Yangzi Delta', *East Asian Science, Technology and Society* 4, 2 (2010): 229-253.

<sup>20</sup> I make use of technological culture in *Technology, Gender and History* (passim) and in Francesca Bray, 'Technological Transitions', in *The Cambridge History of the World*, vol. 6 part 1, *The Construction of a Global World, 1400-1800 C.E.*, edited by Merry Wiesner-Hanks, Jerry H. Bentley and Sanjay Subrahmanyam, Cambridge University Press, 2015: 76-106. I applied the paired concepts to analyze the role of technology in China's transition to modernity in Francesca Bray, 'Technology', in Howard Chiang (ed), *The Making of the Human Sciences in China: Historical and Conceptual Foundations* (Leiden, forthcoming 2017).

<sup>21</sup> Flitsch, 'Knowledge': 268.

<sup>22</sup> Christian Daniels, Volume 6, *Biology and Biological Technology*, Part III, *Agro-industries and Forestry. Agro-industries: Sugarcane Technology*, in Joseph Needham, *Science and Civilisation in China*, Cambridge University Press, 1996.

<sup>23</sup> Peer Högselius, Arne Kaijser and Erik van der Vleuten, *Europe's Infrastructure Transition: Economy, War, Nature*, Springer, 2015: xiii.

<sup>24</sup> Bray, *Technology, Gender and History*.

<sup>25</sup> Thomas J. Misa, *Leonardo to the Internet: Technology and Culture from the Renaissance to the Present*, Johns Hopkins University Press, 2004: 1-32.

<sup>26</sup> Francesca Bray, *Technology and Gender: Fabrics of Power in Late Imperial China*, California University Press, 1997; Jacob Eyferth, 'Women's Work and the Politics of Homespun in Socialist China, 1949-1980', *International Review of Social History* 57, 3 (2012): 365-391.

<sup>27</sup> Misa, *Leonardo*, passim.

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<sup>28</sup> Here beer and brewing play a starring role, evoking the similar prominence of saké production and fermentation more generally in the development of manufacturing in Tokugawa Japan; Tessa Morris-Suzuki, *The technological transformation of Japan: From the seventeenth to the twenty-first century*, Cambridge University Press, 1994.

<sup>29</sup> Eda Kranakis, 'Surveying technology and history: Essential tensions and postmodern possibilities', *Technology and Culture* 46.4 (2005): 805-812; p. 807.

<sup>30</sup> *ibid*: 809, emphases added.

<sup>31</sup> Misa, *Leonardo*: 57.

<sup>32</sup> Francesca Bray, 'Science, technique, technology: passages between matter and knowledge in imperial Chinese agriculture', *British Journal for the History of Science* 41, 3 (2008): 319-344. There I briefly discuss key technologies of the Chinese state, and I compare the styles and strategies of agricultural treatises to show the tensions and contradictions between the technological cultures of state officials and land-owners.

<sup>33</sup> Christine Moll-Murata, Song Jianze and Hans Ulrich Vogel (eds) *Chinese Handicraft Regulations of the Qing Dynasty: Theory and Application*, Iudicum, 2005; Gugong bowuguan (Palace Museum), *Gongting yu difang : shiqi zhi shiba shiji de jishu jiaoliu* (The court and the localities: technological knowledge circulation in the 17th and 18th century), Zijincheng Press, 2010.

<sup>34</sup> Esha Shah, 'Telling otherwise: a historical anthropology of tank irrigation technology in South India', *Technology and Culture* 49, no. 3 (2008): 652-674; pp 653, 655.